Cryptozoology, 6, 1987, 55–64
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THE WILSON NESSIE PHOTO: A SIZE DETERMINATION BASED ON PHYSICAL PRINCIPLES

Paul H. LeBlond and Michael J. Collins
Department of Oceanography, The University of British Columbia,
Vancouver, British Columbia V6T 1W5, Canada

Abstract: We present a calculation of the dimension of Nessie, as seen in the 1934 Wilson photograph, based on a comparison with the length of adjacent wind waves. The wavelength is estimated from modern results on wind waves and contemporaneous weather information. Quantitative comparison of Nessie and the wavelength scale is effected in a digitized version of the original photograph. Our estimate of the height of the neck above the water level is 1.2 m (4 ft), and other possible (subsurface) dimensions may be estimated proportionally. The object thought to be Nessie in the Wilson photograph is therefore of a dimension which warrants all the interest which it has received.

Introduction

The object which appears in a photograph taken in 1934 by a surgeon, Lt. Col. R. Kenneth Wilson (Fig. 1) has commonly been identified with Nessie, the Loch Ness Monster. Its likeness has appeared on souvenirs and logos, and has entered the public perception as the archetypal form of Nessie. Over the years, however, there has arisen much speculation as to the precise nature of what appears in the photograph.

It is not our intention to contribute to the debate on its authenticity, or to add to the bestiary of alternate explanations proposed: otter, killer whale (orca), diving bird, emerging tree trunk, or swimming elephant. The reader may review the critical history of the Wilson photo by consulting the standard works on the topic (Dinsdale 1961, Burton 1961, Holiday 1969, Costello 1974, Witchell 1976, Power and Johnson 1979, Binns 1984, Campbell 1986, Bauer 1986). The point addressed here, which has long been recognized as a major source of uncertainty, is that of the absence of identifiable features capable of providing a scale for Nessie in the photograph. It has been argued that it matters a great deal whether the object is only a few centimeters long, and thus possibly part of a familiar, small animal, or perhaps a couple of meters long, and thus too large to be so easily explained away.

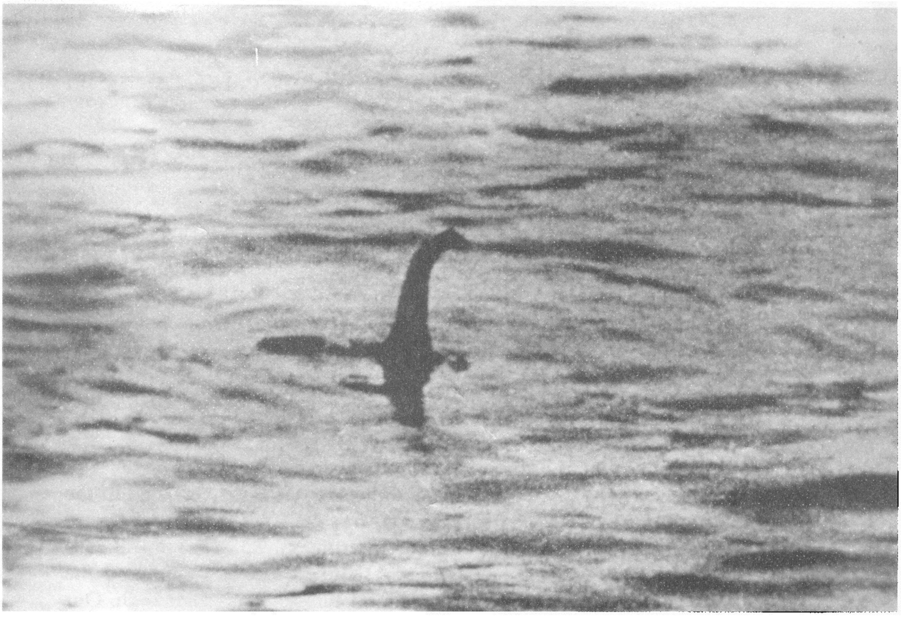

FIG. 1.—The classic photograph of Nessie, a cropped and enlarged version of the photo taken by Lt. Col. Kenneth Wilson at Loch Ness in April of 1934.

Until the early 1980's, only cropped and enlarged versions of the photo (as seen in Fig. 1) have been available for analysis. Holiday (1969) attempted a calculation of the object's dimensions based on a series of assumptions which he felt were too numerous and shaky to inspire much confidence in the result: about 6 ft (1.8 m) for the neck portion emerging above the water level. Recently, Campbell (1984) discovered an uncropped print at Associated Newspapers (Fig. 2), and he then performed a more direct analysis, which yielded an estimate of 0.7 m for the same dimension.[1] Our analysis is complementary to that of Campbell. It uses the wind waves visible in great number in the uncropped positive of the Wilson photo to deduce a scale for Nessie. The method is similar in principle to that used in scaling Champ in the Mansi photograph of the Lake Champlain Monster (LeBlond 1982).

METHOD

A wind-swept sea consists of a confused superposition of waves of a range of lengths and amplitudes, travelling roughly in the direction of the wind (Kinsman 1965). A background of wind waves is thus generally too irregular

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[1] More recently, Alastair Boyd found the uncropped version published in the April 28, 1934, issue of *The Illustrated London News*, which he provided to the author—Editor.

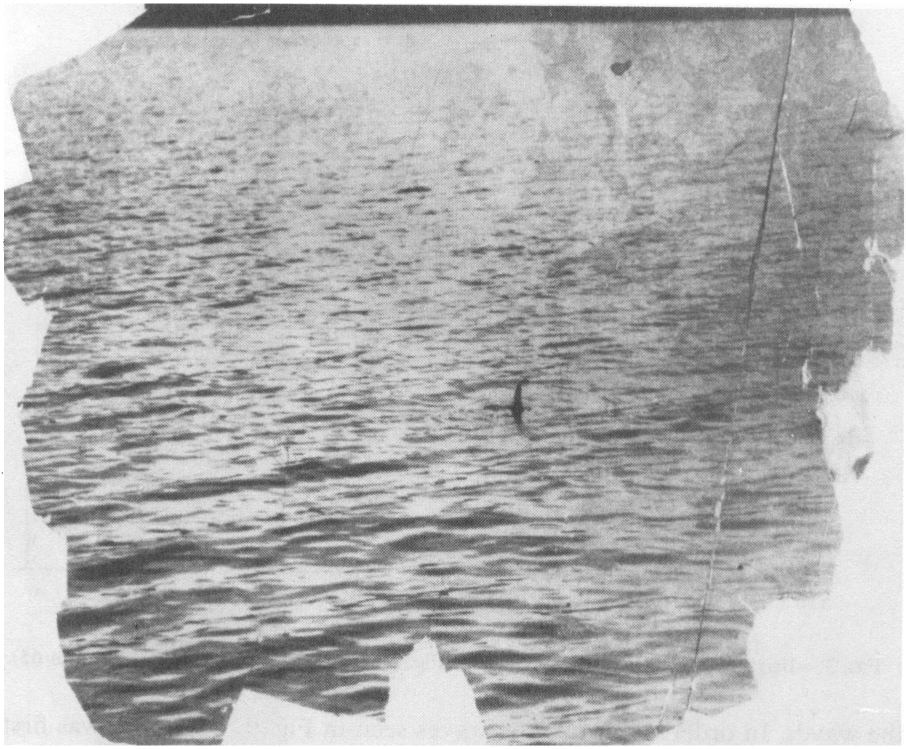

FIG. 2.—The original, uncropped version of the Wilson photo, with opposite shore visible. Note the secondary concentric wave pattern around Nessie; the ellipticity of that pattern has been used by Campbell (1984) to calculate the viewing angle.

to be used as a simple graduated scale against which to measure an object at the sea surface; it may be used as a scale, but only in a rather more subtle way.

The distribution of wave energy among wavelengths (the energy spectrum) has a peak at a wavelength which corresponds closely to the "significant" wavelength which a trained observer would deduce from visual observation. For some angles of view, especially when the waves are seen from the side, as in the Mansi photograph (LeBlond 1982), the significant wavelength is easily determined. This is not the case for the Wilson photo (also known as "the surgeon's photo"), where the wave field is seen nearly head-on. Although we shall attempt a simple scale comparison with what appears to be a single wavelength near Nessie, we shall also use a more objective method based on a quantitative analysis of the wave field.

The distribution of energy among waves of different lengths is usually determined by sampling over a large number of waves, either in time, at a fixed point, or over a broad enough area to average out the irregularities of

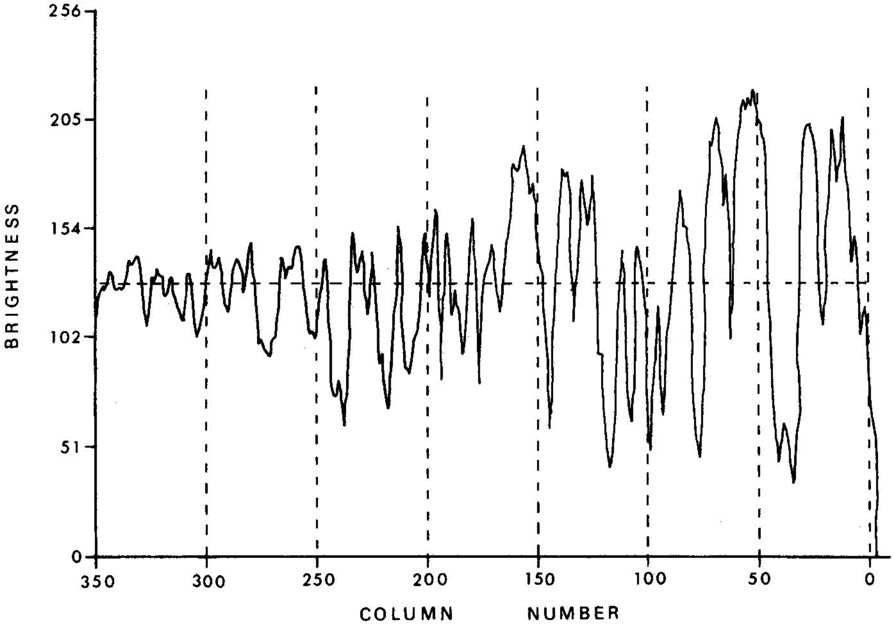

FIG. 3.—Brightness variation along a slice of Fig. 2 near Nessie (which is near column 65).

the waves. In order to sample the waves seen in Fig. 2, the image was first digitized into an array of 512 × 512 pixels of brightness levels ranging from white to black over 256 steps of a gray scale. The brightness level depends on the intensity of reflected sunlight, and hence on wave slope, rather than height. This is an important point in interpreting our results. Brightness levels were sampled along fourteen parallel slices running in the direction of wave propagation, i.e., perpendicular to the wave crests. Fig. 3 shows an example of brightness variation along one of the slices. The numbers of crossings by the brightness curve of its average value were counted over

TABLE 1.—Zero-crossing statistics of brightness fluctuations in the image plane, based on 14 slices such as that shown in Fig. 3. n is the number of zero crossings in each $\Delta y = 50$ pixel interval in the direction of wave propagation (20° from the left of the image vertical), y is the middle pixel value for each interval from the beginning of the slice, at the bottom of the image, $y_m = 350$ is the maximum number of pixels in a slice.

y	n	y/y_m	$n(1 - y/y_m)^2$
25	4.6	0.07	4.0
75	6.5	0.21	4.05
125	9.4	0.36	3.9
175	10.3	0.5	2.6
225	10.5	0.64	1.36

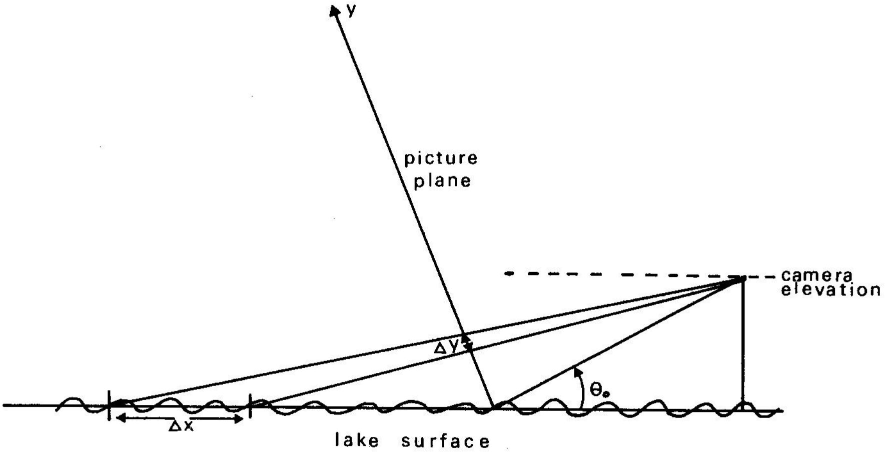

FIG. 4.—Geometrical relations between segments in the plane of the lake surface and the image plane. The viewing angle θ_o is calculated from the ellipticity of the pattern in Fig. 2.

segments of 50 pixels along a slice and averaged over all slices. These numbers appear in Table 1. They will be used to determine the average wavelength L on the basis of two zero-crossings per wavelength.

Since the waves are not seen directly from above, their apparent spacing changes with position in the image: the nearest waves appear longer in Fig. 2. With reference to Fig. 4, we find that a segment Δx in the plane of the lake surface is related to a segment Δy of the picture plane through

$$\Delta x = \frac{\Delta y}{\sin \theta_o (1 - y/y_m)^2}, \tag{1}$$

where y is the distance from a reference point on the picture plane, y_m the maximum value of that distance, and θ_o the angle which the picture plane makes with the vertical. We assume that the wave field is statistically homogeneous over the part of the image in which we are interested, so that the compression of wavelengths with distance is entirely due to the angle of view. If there are n brightness zero-crossings over a chosen picture plane interval Δy, then $\Delta x = nL/2$, and from (1) we expect that

$$n(1 - y/y_m)^2 = 2\Delta y/(L \sin \theta_o) \tag{2}$$

should be a constant over a range of values of y. Table 1 lists average zero-crossing counts over six $\Delta y = 50$ pixel intervals in the image plane and corresponding estimates of the left-hand side of (2). The angle θ_o is taken, as in Campbell (1984), from the apparent ellipticity of the secondary wave patterns concentric to Nessie as $\theta_o = 19°$. The number of pixels per average wavelength L of the brightness fluctuations may then be evaluated from (2).

The dimensions of Nessie, in terms of numbers of pixels, may thus be expressed in terms of wavelengths.

The final step is, of course, to obtain an estimate of the actual physical dimension of a wavelength. The length of wind waves increases with wind speed, duration, and fetch; empirical results for growing waves are given by Carter (1982). For sufficiently long duration and fetch, waves stop growing and lengthening: the sea is said to be fully developed. Under such conditions, and we shall discuss whether they could have been achieved at the time, the wavelength L_m corresponding to the peak of the spectrum in deep water (deeper than a wavelength) is given (in meters) by

$$L_m = 0.83\ U^2, \tag{3}$$

where U is the wind speed at a height of 10 m above the water surface, in m/s. Since Loch Ness is long in terms of the fetch required to set up a fully developed sea at the low wind speeds considered (about 20 km), we shall remark only on the possibility of the wind field being duration-limited. From Carter (1982: Appendix A) we find that for duration limited waves

$$L_m = 0.45\ D^{0.86} U^{1.14}, \tag{4}$$

where D is the duration of the wind of speed U (in hours).

Wind information was obtained from the National Meteorological Library, Bracknell, Berkshire, England, for the presumed date on which the photograph was taken: April 19, 1934, at about 7:00 a.m. (cf. Campbell 1984, for a discussion of that date). On that morning, the nearest Scottish weather stations, at Dalwhinnie (at 56°56′N, 04°14′W) and Aberdeen, respectively reported calm conditions (no wind) and winds from the west-north-west at force 3 (3.5–5.0 m/s). Neither station is representative of conditions at the Loch. The former is located 23 miles southeast of Invermoriston, Loch Ness; the latter, on the shores of the North Sea, is about 90 miles east of Invermoriston. We may, however, take the weak wind conditions measured at the weather stations, together with the surface atmospheric pressure map issued on that morning, as indicative of weather conditions over most of Scotland.

More specific information at Loch Ness comes from the photograph itself. The appearance of the sea surface changes gradually as the wind speed increases in a manner formalized in the Beaufort Scale (Allen 1983). The critical point to note here is that there is not a single breaker visible in Fig. 2. This observation limits the wind speed to force 2 (U = 2.5–3.0 m/s). This is consistent with observations by Monahan (1971) of whitecap coverage, as well as with the general meteorological conditions for that morning.

We now have in hand all the elements necessary to relate the apparent dimensions of Nessie in Fig. 2 to those of the waves, and to obtain an estimate for the physical wavelength itself in terms of the wind speed. We shall reserve the discussion of possible errors for a later section.

RESULTS

Let us first estimate the wavelength of the spectral peak from observed wind conditions. We shall assume that the wind was blowing from the north end of the Loch, as inferred from the photograph and from the general weather conditions, at a speed appropriate to Beaufort force 2: $U = 3.0$ m/ s. The presumed location of the photograph, 2–3 miles on the Inverness side of Invermoriston, gives an upwind fetch of about 20 km. From Carter (1982), a duration of 6 hr is required for the full development of a wind sea for that fetch and wind speed. From (3), $L_m = 7.5$ m under those conditions. It is quite conceivable, however, and perhaps more likely in view of the frequent diurnal modulation of valley winds, that the wind might not have been blowing for 6 hr or more. Wilson's recollections, as quoted by Campbell (1984), are uninformative in this respect. For a shorter duration, $D = 3$ hr, (4) yields $L_m = 4.0$ m.

The other point to recall is that what is observed in Fig. 2 is a distribution of wave slopes, not of wave amplitudes. The results just quoted for L_m are for wave amplitudes; the slope spectrum is obtained from the displacement spectrum by dividing by the square of the wavelength; its peak occurs at shorter wavelengths. The JONSWAP spectrum appropriate for growing seas is quite steep, and a modicum of algebra shows that the length L of the peak of the slope spectrum is very near L_m: $L = 0.95\ L_m$. The difference is too small to be of concern to us in the present context.

In view of the above, and on the basis of the first author's personal experience with a similar sea state on Loch Ness, we shall adopt $L = 4.0$ m as the wavelength of the brightness fluctuations in Fig. 2. The reader will, of course, be aware of the subjective aspect of this choice, and may wish to scale the results up to $L = 7.5$ m, which would correspond to the absolute upper limit for the wind force and sea development.

It is useful at first to short-circuit the painstaking pixel counting process leading to (2), and to perform a direct—if rather subjective–visual comparison of Nessie with nearest wave. In Fig. 2, we judge that Nessie occupies about 70% of the vertical distance in the image plane between the nearest dark bands on either side of it. A correction by the factor $(1/\cos[20°] = 1.06)$ to take into account the angle of propagation of the waves brings that ratio up to 74%. Taking the viewing angle into account, as shown in Fig. 5, we have $h/x = \tan(19°)$. With $x = 0.74\ L$, $h = 1.06$ m (3.5 ft). This estimate is surprisingly close to that originally given by Wilson (Anonymous 1934), who reported: "I saw a long neck, about three feet out of the water, and a head which looked small."

Results of the more objective wavelength estimation based on zero-cross-

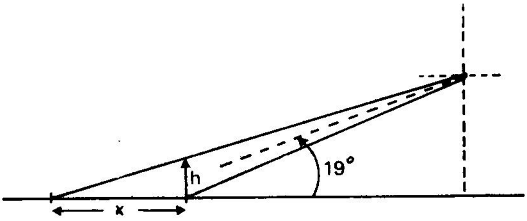

FIG. 5.—The geometry pertinent to calculation of Nessie dimension from comparison with wavelength.

ings are included in Table 1. The last column gives estimates of the right-hand side of (2) for a sequence of bands of 50 pixels in the image plane; these numbers should all be the same for purely geometrical distortion. Because the fourth and fifth bands correspond to the top of the image, where digitization leads to serious loss of resolution, we are satisfied that the wave field seen in the first three bands is homogeneous, and that the value 4.0 may be used for the right-hand side of (2). We then calculate

$$L = \frac{y}{2\sin(19°)} = 77 \text{ pixels}$$

in the plane of the lake surface. In the image plane, a wavelength then covers L sin(19°) = 25 pixels. The dimensions of Nessie in terms of pixels in the image plane are shown in Fig. 6. Instead of 70% of a wavelength, as in the above "simple" analysis, we now have 22/25 = 88% (there is no need to apply the 1/cos[20°] correction since the wavelength is already calculated in the direction of wave motion). Using the same viewing angle as above, the geometry of Fig. 5 now gives h = 0.88 L tan(19°) = 1.21 m (4 ft).

DISCUSSION

Our analysis yields a value of 1.2 m (4 ft) for the height of Nessie's neck as it appears in the photograph. Other possible (subsurface) dimensions may be estimated in proportion from Fig. 6. We have discussed and presented all assumptions made in obtaining this result, so that the reader may be aware of its limitations. The most important assumption concerns the duration of the wind before the photograph was taken. Shorter (1 hr) or longer (6 hr) assumed durations change the wavelength of wind waves up or down by a factor of two, with a similar effect on Nessie's size estimate.

The results are too inconclusive to draw specific biological conclusions, although perhaps the bird hypothesis can be discarded. From a general point of view, we find that the object seen in Fig. 2 is of a dimension which certainly warrants all the interest which it has received and the mystery which surrounds it.

We are grateful to Tom Lee, of the University of British Columbia Com-

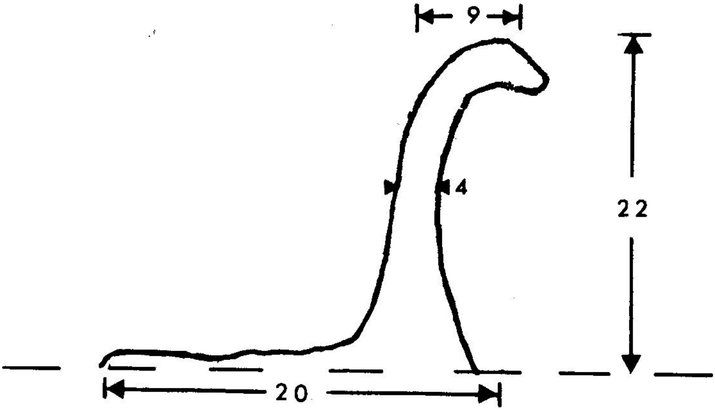

FIG. 6.—Pixel dimensions of Nessie in the image plane, based on a 512 × 512 digitization of Fig. 2. Drawing not necessarily accurate.

puting Centre, for his assistance in image digitization, to Paul Nowlan and Andrew Thomas, of the Satellite Oceanography Laboratory, for their advice in image manipulation, to R. M. Mason, of the National Meteorological Library, United Kingdom, for providing weather information, to J. Richard Greenwell for his bibliographic assistance, and to Alastair Boyd for pointing out to us Wilson's original estimate of Nessie's dimensions.

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